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Information and the Change in the Paradigm in Economics[†]

By Joseph E. Stiglitz*

The research for which George Akerlof, Michael Spence, and I are being recognized is part of a larger research program which today embraces a great number of researchers around the world. In this article, I want to set the particular work which was cited within this broader agenda, and that agenda within the still broader perspective of the history of economic thought. I hope to show that information economics represents a fundamental change in the prevailing paradigm within economics.

Information economics has already had a profound effect on how we think about economic policy and is likely to have an even greater influence in the future. Many of the major policy debates over the past two decades have centered around the related issues of the efficiency of the market economy and the appropriate relationship between the market and the government. The argument of Adam Smith (1776) that free markets lead to efficient outcomes, "as if by an invisible hand," has played a central role in these debates: It suggested that we could, by and large, rely on markets *without government intervention* (or, at most, with a limited role for government). The set of ideas that I will present here undermined Smith's theory and the view of the role of government that rested on it. They have suggested that the reason that the hand may be invisible is that it is simply not there—or at least that if is there, it is palsied.

When I began the study of economics some 41 years ago, I was struck by the incongruity between the models that I was taught and the world that I had seen growing up in Gary, Indiana. Founded in 1906 by U.S. Steel, and

named after its Chairman of the Board, Gary has declined to but a shadow of its former self. But even in its heyday, it was marred by poverty, periods of high unemployment, and massive racial discrimination. Yet the economic theories we were taught paid little attention to poverty, said that all markets cleared—including the labor market, so that unemployment must be nothing more than a phantasm—and claimed that the profit motive ensured that there could not be economic discrimination (Gary Becker, 1971). As a graduate student, I was determined to try to create models with assumptions—and conclusions—closer to those that accorded with the world I saw, with all of its imperfections.

My first visits to the developing world in 1967, and a more extensive stay in Kenya in 1969, made an indelible impression on me. Models of perfect markets, as badly flawed as they might seem for Europe or America, seemed truly inappropriate for these countries. While many of the key assumptions that went into the competitive equilibrium model seemed not to fit these economies well, I was particularly struck by the imperfections of information, the absence of markets, and the pervasiveness and persistence of seemingly dysfunctional institutions, such as sharecropping. I had seen cyclical unemployment—sometimes quite large—and the hardship it brought as I grew up, but I had not seen the massive unemployment that characterized African cities, unemployment that could not be explained either by unions or minimum wage laws (which, even when they existed, were regularly circumvented). Again, there was a massive discrepancy between the models we had been taught and what I saw.

In contrast, the ideas and models I will discuss here have proved useful not only in addressing broad philosophical questions, such as the appropriate role of the state, but also in analyzing concrete policy issues. For example, I believe that some of the huge mistakes which have been made in policy in the last decade, in for instance the management of the East Asian

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crisis or the transition of the former communist countries to the market, might have been avoided had there been a better understanding of issues—such as financial structure, bankruptcy, and corporate governance—to which the new information economics has called attention. And the so-called "Washington consensus"[1] policies, which have predominated in the policy advice of the international financial institutions over the past quarter century, have been based on market fundamentalist policies which ignored the information-theoretic concerns; this explains, at least partly, their widespread failures. Information affects decision-making in every context—not just inside firms and households. More recently, as I discuss below, I have turned my attention to some aspects of what might be called the *political economy* of information: the role of information in political processes and collective decision-making. There are asymmetries of information between those governing and those governed, and just as participants in markets strive to overcome asymmetries of information, we need to look for ways by which the asymmetries of information in political processes can be limited and their consequences mitigated.

I. The Historical Setting

I do not want here to review in detail the models that were constructed exploring the role of information; in recent years, there has been a number of survey articles and interpretive essays, even several books in this area.[2] I do want to highlight some of the dramatic impacts that information economics has had on how economics is approached today, how it has provided explanations for phenomena that were previously unexplained, how it has altered our views about how the economy functions, and, perhaps most importantly, how it has led to a rethinking of the appropriate role for government in our society. In describing the ideas, I want to trace out some of their origins. To a large extent, these ideas evolved from attempts to answer specific policy questions or to explain specific phenomena to which the standard theory provided an inadequate explanation. But any discipline has a life of its own, a prevailing paradigm, with assumptions and conventions. Much of the work was motivated by an attempt to explore the limits of that paradigm—to see how the standard models could embrace problems of information imperfections (which turned out to be not very well).

For more than 100 years, formal modeling in economics had focused on models in which information was assumed to be perfect. Of course, everyone recognized that information was in fact imperfect, but the hope, following Marshall's dictum "*Natura non facit saltum*," was that economies in which information was not too imperfect would look very much like economies in which information was perfect. One of the main results of our research was to show that this was not true; that even a small amount of information imperfection could have a profound effect on the nature of the equilibrium.

The creators of the neoclassical model, the reigning economic paradigm of the twentieth century, ignored the warnings of nineteenth-century and still earlier masters about how information concerns might alter their analyses—perhaps because they could not see how to embrace them in their seemingly precise models, perhaps because doing so would have led to uncomfortable conclusions about the efficiency of markets. For instance, Smith, in anticipating later discussions of adverse selection, wrote that as firms raise interest rates, the best borrowers drop out of the market.[3] If lenders knew perfectly the risks associated with each borrower, this would matter little; each borrower would be charged an appropriate risk premium. It is because lenders do

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[1] See John Williamson (1990) for a description and Stiglitz (1999c) for a critique.

[2] Review articles include Stiglitz (1975b, 1985d, 1987a, 1988b, 1992a, 2000d) and John G. Riley (2001). Book-length references include, among others, Drew Fudenberg and Jean Tirole (1991), Jack Hirshleifer and Riley (1992), and Oliver D. Hart (1995).

[3] "If the legal rate ... was fixed so high ... the greater part of the money which was to be lent, would be lent to prodigals and profectors, who alone would be willing to give this higher interest. Sober people, who will give for the use of money no more than a part of what they are likely to make by the use of it, would not venture into the competition" (Smith, 1776). See also Jean-Charles-Leonard Simonde de Sismondi (1815), John S. Mill (1848), and Alfred Marshall (1890), as cited in Stiglitz (1987a).

not know the default probabilities of borrowers perfectly that this process of adverse selection has such important consequences.

I have already noted that *something* was wrong—indeed seriously wrong—with the competitive equilibrium models which represented the prevailing paradigm when we went to graduate school. The paradigm seemed to say that unemployment did not exist, and that issues of efficiency and equity could be neatly separated, so that economists could set aside problems of inequality and poverty as they went about their business of designing more efficient economic systems. But beyond these questionable conclusions there were also a host of empirical puzzles—facts that were hard to reconcile with the standard theory, institutional arrangements left unexplained. In microeconomics, there were public finance puzzles, such as why firms appear not to take actions which minimize their tax liabilities; security market paradoxes,[4] such as why asset prices are so volatile (Robert J. Shiller, 2000) and why equity plays such a limited role in the financing of new investment (Colin Mayer, 1990); and other important behavioral questions, such as why firms respond to risks in ways markedly different from those predicted by the theory. In macroeconomics, the cyclical movements of many of the key aggregate variables proved difficult to reconcile with the standard theory. For example, if labor-supply curves are highly inelastic, as most evidence suggests is the case (especially for primary workers), then falls in employment during cyclical downturns should be accompanied by large declines in the real consumption wage. This does not appear to happen. And if the perfect market assumptions were even approximately satisfied, the distress caused by cyclical movements in the economy would be much less than seems to be the case.[5]

There were, to be sure, some Ptolemaic attempts to defend and elaborate on the old model. Some authors, like George J. Stigler (1961), Nobel laureate in 1982, while recognizing the importance of information, argued that once the real costs of information were taken into account, the standard results of economics would still hold. Information was just a transactions cost. In the approach of many Chicago School economists, information economics was like any other branch of applied economics; one simply analyzed the special factors determining the demand for and supply of information, just as one might analyze the factors affecting the market for wheat. For the more mathematically inclined, information could be incorporated into production functions by inserting an I for the input "information," where I itself could be produced by inputs, like labor. Our analysis showed that this approach was wrong, as were the conclusions derived from it.

Practical economists who could not ignore the bouts of unemployment which had plagued capitalism since its inception talked of the "neoclassical synthesis": If Keynesian interventions were used to ensure that the economy remained at full employment, the story went, the standard neoclassical propositions would once again be true. But while the neoclassical synthesis (Paul A. Samuelson [1947], Nobel laureate in 1970) had enormous intellectual influence, by the 1970's and 1980's it had come under attack from two sides. One side attacked the underpinnings of Keynesian economics, its microfoundations. Why would rational actors fail to achieve equilibrium—with unemployment persisting—in the way that John Maynard Keynes (1936) had suggested? This form of the argument effectively denied the existence of the phenomena that Keynes was attempting to explain. Worse still, from this perspective some saw the unemployment that did exist as largely reflecting an interference (e.g., by government in setting minimum wages, or by trade unions using their monopoly power to set too-high wages) with the free workings of the market. The implication was that unemployment would be eliminated if markets were made more *flexible*, that is, if unions and government interventions were eliminated. Even if wages fell by a third in the Great Depression, they should have, in this view, fallen even more.

There was however an alternative perspective (articulated more fully in Bruce C. Greenwald

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[4] There was so many of these that the *Journal of Economic Perspectives* ran a regular column with each issue highlighting these paradoxes. For a discussion of other paradoxes, see Stiglitz (1973b, 1982d, 1989g).

[5] Robert E. Lucas, Jr. (1987), who won the Nobel Prize in 1995, uses the perfect markets model with a representative agent to try to argue that these cyclical fluctuations in fact have a relatively small welfare costs.

and Stiglitz, 1987a, 1988b) which asked why we shouldn't believe that massive unemployment was just the tip of an iceberg of more pervasive market efficiencies that are harder to detect. If markets seemed to function *so* badly some of the time, they must be underperforming in more subtle ways much of the time. The economics of information bolstered this view. Indeed, given the nature of the debt contracts, falling prices in the Depression led to bankruptcy and economic disruptions, actually exacerbating the economic downturn. Had there been more wage and price flexibility, matters might have been even worse.

In a later section, I shall explain how it was not just the discrepancies between the standard competitive model and its predictions which led to its being questioned, but the model's lack of robustness—even slight departures from the underlying assumption of perfect information had large consequences. But before turning to those issues, it may be useful to describe some of the specific questions which underlay the beginnings of my research program in this area.

II. Some Motivating Ideas

A. *Education as a Screening Device*

Key to my thinking on these issues was the time between 1969 and 1971 I spent at the Institute for Development Studies at the University of Nairobi with the support of the Rockefeller Foundation. The newly independent Kenyan government was asking questions that had not been raised by its former colonial masters, as it attempted to forge policies which would promote its growth and development. For example, how much should the government invest in education? It was clear that a better education got people better jobs—the credential put one at the head of the job queue. Gary S. Fields, a young scholar working at the Institute of Development Studies there, developed a simple model (published in 1972) suggesting, however, that the private returns to education—the enhanced probability of getting a good job—might differ from the social return. Indeed, it was possible that as more people got educated, the private returns got higher (it was even more necessary to get the credential) even though the

social return to education might decline. From this perspective, education was performing a markedly different function than it did in the traditional economics literature, where it simply added to human capital and improved productivity.[6] This analysis had important implications for Kenya's decision about how much to invest in higher education. The problem with Fields' work was that it did not provide a full *equilibrium* analysis: wages were fixed, rather than competitively determined.

This omission led me to ask what the market equilibrium would look like if wages were set equal to mean marginal products *conditional on the information that was available* (Stiglitz, 1975c). And this in turn forced me to ask: what were the *incentives* and *mechanisms* for employers and employees to acquire or transmit information? Within a group of otherwise similar job applicants (who therefore face the same wage), the employer has an incentive to identify who is the most able, to find some way of *sorting* or *screening* among them, *if he could keep that information private*. But often he cannot; and if others find out about a worker's true ability, the wage will be bid up, and the employer will be unable to appropriate the return to the information. At the very beginning of this research program we had thus identified one of the key issues in information economics: the difficulty of *appropriating* the returns to creating information.

On the other hand, if the employee knew his own ability (that is, if there were *asymmetries of information* between the employee and the employer), then a different set of incentives were at play. Someone who knows his abilities are above average has an incentive to convince his potential employer of that, but a worker at the bottom of the ability distribution has an equally strong incentive to keep the information private. Here was a second principle that was to be explored in subsequent years: there are incentives on the part of individuals for information not to be revealed, for secrecy, or, in modern

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[6] See, e.g., Theodore W. Schultz (1960), who won the Nobel Prize in 1979, and Jacob Mincer (1974). At the time, there was other ongoing work criticizing the human-capital formulation, which focused on the role of education in socialization and providing credentials; see, for example, Samuel Bowles and Herbert Gintis (1976).

parlance, for a lack of transparency. This raised questions: How did the forces for secrecy and for information disclosure get balanced? What was the equilibrium that emerged? I will postpone until the next section a description of that equilibrium.

B. *Efficiency Wage Theory*

That summer in Kenya I began three other research projects related to information imperfections. At the time I was working in Kenya, there was heavy urban unemployment. My colleagues at the Institute for Development Studies, Michael Todaro and John Harris, had formulated a simple model of labor migration from the rural to the urban sector which accounted for the unemployment.[7] High urban wages attracted workers, who were willing to risk unemployment for the chance at those higher wages. Here was a simple, general-equilibrium model of unemployment, but again there was one missing piece: an explanation of high urban wages, well in excess of the legal minimum wage. It did not seem as if either government or unions were *forcing* employers to pay these high wages. One needed an equilibrium theory of wage determination. I recalled discussions I had once had in Cambridge with Harvey Leibenstein, who had postulated that in very poor countries, because of nutrition, higher wages led to higher productivity (Leibenstein, 1957). The key insight was that imperfections in information and contracting might also rationalize a dependence of productivity on wages.[8] In that case, firms might find it profitable to pay a higher wage than the minimum necessary to hire labor; such wages I referred to as *efficiency wages*. With efficiency wages, unemployment could exist in equilibrium. I explored four explanations for why productivity might depend on wages (other than through nutrition). The simplest was that lower wages lead to higher

turnover, and therefore higher turnover costs for the firm.[9] It was not until some years later than we were able to explain more fully—based on limitations of information—why it was that firms have to bear these turnover costs (Richard J. Arnott and Stiglitz, 1985; Arnott et al., 1988).

Another explanation for efficiency wages was related to the work I was beginning on asymmetric information. Any manager will tell you that paying higher wages attracts better workers—this is just an application of the general notion of adverse selection, which played a central role in earlier insurance literature (Kenneth J. Arrow, 1965). Firms in a market do not passively have to accept the "market wage." Even in competitive markets, firms could, if they wanted, offer higher wages than others; indeed, it might pay a firm to offer a higher wage, to attract more able workers. Again, the efficiency wage theory explained the existence of unemployment *in equilibrium*. It was thus clear that the notion that underlay much of traditional competitive equilibrium analysis—that markets *had* to clear—was simply not true if information were imperfect.

The formulation of the efficiency wage theory that has received the most attention over the years, however, has focused on problems of *incentives*. Many firms claim that paying high wages induces their workers to work harder. The problem that Carl Shapiro and I (1984) faced was to try to make sense of this claim. If all workers are identical, then if it benefited one firm to pay a high wage, it would likewise benefit all firms. But if a worker was fired for shirking, and there were full employment, he

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[7] See Michael P. Todaro (1969) and John R. Harris and Todaro (1970). I developed these ideas further in Stiglitz (1969b).

[8] Others were independently coming to the same insight, in particular, Edmund S. Phelps (1968). Phelps and Sidney G. Winter (1970) also realized that the same issues applied to product markets, in their theory of customer markets.

[9] In Nairobi, in 1969, I wrote a long, comprehensive analysis of efficiency wages, entitled "Alternative Theories of Wage Determination and Unemployment in LDC's." Given the custom of writing relatively short papers, focusing on one issue at a time, rather than publishing the paper as a whole, I had to break the paper down into several parts. Each of these had a long gestation period. The labor turnover paper was published as Stiglitz (1974a); the adverse selection model as Stiglitz (1982a, 1992d [a revision of a 1976 unpublished paper]). I elaborated on the nutritional efficiency wage theory in Stiglitz (1976). Various versions of these ideas have subsequently been elaborated on in a large number of papers, including Andrew W. Weiss (1980), Stiglitz (1982f, 1986b, 1987a, 1987g), Akerlof and Yellen (1986), Andrés Rodríguez and Stiglitz (1991a, b), Raaj K. Sah and Stiglitz (1992), Barry J. Nalebuff et al. (1993), and Patrick Rey and Stiglitz (1996).

could immediately get another job at the same wage. The high wage would thus provide no incentive. Only if there were unemployment would the worker pay a price for shirking. We showed that *in equilibrium* there *had* to be unemployment: unemployment was the discipline device that forced workers to work hard (see Rey and Stiglitz [1996] for an alternative general-equilibrium formulation). The model had strong policy implications, some of which I shall describe below. Our work illustrated the use of highly simplified models to help clarify thinking about quite complicated matters. In practice, of course, workers are not identical, so problems of adverse selection become intertwined with those of incentives. For example, being fired usually does convey information—there is typically a stigma.

There was a fourth version of the efficiency wage, where productivity was related to *morale* effects, perceptions about how *fairly* they were being treated. While I briefly discussed this version in my earlier work (see in particular Stiglitz, 1974d), it was not until almost 20 years later that the idea was fully developed in the important work of Akerlof and Yellen (1990).

C. *Sharecropping and the General Theory of Incentives*

This work on the economics of incentives in labor markets was closely related to the third research project that I began in Kenya. In traditional economic theory, while considerable lip service was paid to incentives, there was little serious attention to issues of incentives, motivation, and monitoring. With perfect information, individuals are paid to perform a particular service. If they perform the service they receive the contracted amount; and if not, they do not. With *imperfect* information, firms have to motivate and monitor, rewarding workers for observed good performance and punishing them for bad. My interest in these issues was first aroused by thinking about sharecropping, a common form of land tenancy in developing countries. Under sharecropping, the worker surrenders half (sometimes two-thirds) of the produce to the landlord in return for the use of his land. At first blush, this seemed a highly inefficient arrangement, equivalent to a 50-percent tax on workers' labor. But what were the alter-

natives? The worker could rent the land. He would have full incentives but then he would have to bear all the risk of fluctuations in output; and beside, he often did not have the requisite capital to pay the rent ahead of time and access to credit was limited (for reasons to be explained below). He could work as wage labor, but then the landlord would have to monitor him, to ensure that he worked. Sharecropping represented a compromise between balancing concerns about risk sharing and incentives. The underlying information problem was that the input of the worker could not be observed, but only his output, which was not perfectly correlated with his input. The sharecropping contract could be thought of as a combination of a rental contract *plus* an insurance contract, in which the landlord "rebates" part of the rent if crops turn out badly. There is not full insurance (which would be equivalent to a wage contract) because such insurance would attenuate all incentives. The adverse effect of insurance on incentives to avoid the insured-against contingency is referred to as *moral hazard*.[10]

In Stiglitz (1974b) I analyzed the equilibrium sharecropping contract. In that paper, I recognized the similarity of the incentive problems I explored to those facing modern corporations, e.g., in providing incentives to their managers—a type of problem later to be called the *principal-agent problem* (Stephen A. Ross, 1973). There followed a large literature on optimal and equilibrium incentive schemes, in labor, capital, and insurance markets.[11] An important principle was that contracts had to be based on *observables*, whether they be inputs, processes, or outcomes. Many of the results obtained earlier in the work on adverse selection had their par-

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[10] This term, like adverse selection, originates in the insurance literature. Insurance firms recognized that the greater the insurance coverage, the less incentive there was for the insured to take care; if a property was insured for more than 100 percent of its value, there was even an incentive to have an accident (a fire). Not taking appropriate care was thought to be "immoral"; hence the name. Arrow's work in moral hazard (Arrow, 1963, 1965) was among the most important precursors, as it was in the economics of adverse selection.

[11] For a classic reference see Hart and Bengt Holmström (1987). In addition, see Stiglitz (1975a, 1982c), Kevin J. Murphy (1985), Michael C. Jensen and Murphy (1990), Joseph G. Haubrich (1994), and Brian J. Hall and Jeffrey B. Liebman (1998).

allel in this area of "adverse incentives." For instance, Arnott and I (1988a, 1990) analyzed equilibria which entail partial insurance as a way of mitigating the adverse incentive effects (just as partial insurance characterized equilibrium with adverse selection).

D. Equilibrium Wage and Price Distributions

The fourth strand of my research looked at the issue of wage differentials from a different perspective. My earlier work had suggested that firms that faced higher turnover might pay higher wages to mitigate the problem. But one of the reasons that individuals quit is to obtain a higher-paying job, so the turnover rate in turn depends on the wage distribution. The challenge was to formulate an *equilibrium* model that incorporated both of these observations, that is, where the wage distribution *itself* which motivated the search was *explained* as part of the equilibrium.

More generally, efficiency wage theory said that firms might pay a higher wage than necessary to obtain workers; but the level of the efficiency wage might vary across firms. For example, firms with higher turnover costs, or for which worker inefficiency could lead to large losses of capital, or for which monitoring was more difficult, might find it desirable to pay higher wages. The implication was that similar labor might receive quite different compensation in different jobs. The distribution of wages might not, in general, be explicable solely in terms of differences in abilities.

I was to return to these four themes repeatedly in my research over the following three decades.

III. From the Competitive Paradigm to the Information Paradigm

In the previous section, I described how the disparities between the models economists used and the world that I saw, especially in Kenya, had motivated a search for an alternative paradigm. But there was another motivation, driven more by the internal logic and structure of the competitive model itself.

The competitive model virtually made economics a branch of engineering (no aspersions on that noble profession intended), and the par-

ticipants in the economy better or worse engineers. Each was solving a maximization problem, with full information: households maximizing utility subject to budget constraints, firms maximizing profits (market value), and the two interacting in competitive product, labor, and capital markets. One of the peculiar implications was that there never were disagreements about what the firm should do. Alternative management teams would presumably come up with the same solution to the maximization problems. Another peculiar implication was for the meaning of risk: When a firm said that a project was risky, that (should have) meant that it was highly correlated with the business cycle, not that it had a high chance of failure (Stiglitz, 1989g). I have already described some of the other peculiar implications of the model: the fact that there was no unemployment or credit rationing, that it focused on only a limited subset of the information problems facing society, that it seemed not to address issues such as incentives and motivation.

But much of the research in the profession was directed not at these big gaps, but at seemingly more technical issues—at the mathematical structures. The underlying *mathematics* required assumptions of convexity and continuity, and with these assumptions one could prove the existence of equilibrium and its (Pareto) efficiency (see Gerard Debreu, 1959; Arrow, 1964). The standard proofs of these fundamental theorems of welfare economics did not even list in their enumerated assumptions those concerning information: the perfect information assumption was so ingrained it did not have to be explicitly stated. The *economic* assumptions to which the proofs of efficiency called attention concerned the absence of externalities and public goods. The market failures approach to the economics of the public sector (Francis M. Bator, 1958) discussed alternative approaches by which these market failures could be corrected, but these market failures were highly circumscribed by assumption.

There was, moreover, a curious disjunction between the language economists used to explain markets and the models they constructed. They talked about the information efficiency of the market economy, though they focused on a single information problem, that of scarcity. But there are a myriad of other information prob-

lems faced by consumers and firms every day, concerning, for instance, the prices and qualities of the various objects that are for sale in the market, the quality and efforts of the workers they hire, or the potential returns to investment projects. In the standard paradigm, the competitive general-equilibrium model (for which Kenneth J. Arrow and Gerard Debreu received Nobel Prizes in 1972 and 1983, respectively), there were no shocks, no unanticipated events: At the beginning of time, the full equilibrium was solved, and everything from then on was an unfolding over time of what had been planned in each of the contingencies. In the real world, the critical question was: how, and how well, do markets handle fundamental problems of information?

There were other aspects of the standard paradigm that seemed hard to accept. It argued that institutions did not matter—markets could see through them, and equilibrium was simply determined by the laws of supply and demand. It said that the distribution of wealth did not matter, so long as there were well-defined property rights (Ronald H. Coase [1960], who won the Nobel Prize in 1991). And it said that (by and large) history did not matter—knowing preferences and technology and initial endowments, one could describe the time path of the economy.

Work on the economics of information began by questioning each of these underlying premises. Consider, to begin with, the convexity assumptions which corresponded to long-standing principles of diminishing returns. With imperfect information (and the costs of acquiring it) these assumptions were no longer plausible. It was not just that the cost of acquiring information could be viewed as fixed costs.[12] My work with Roy Radner (Radner and

Stiglitz, 1984) showed that there was a *fundamental nonconcavity in the value of information,* that is, under quite general conditions, it never paid to buy just a little bit of information. Arnott and Stiglitz (1988a) showed that such problems were pervasive in even the simplest of moral hazard problems (where individuals had a choice of alternative actions, e.g. the amount of risk to undertake). While we had not repealed the law of diminishing returns, we had shown its domain to be more limited than had previously been realized.

Michael Rothschild and I (1976) showed that under natural formulations of what might be meant by a competitive market with imperfect information, equilibrium often did not exist[13]— even when there was an arbitrarily small amount of information imperfection.[14] While subsequent research has looked for alternative definitions of equilibrium (e.g., Riley, 1979), we remain unconvinced; most of these alternatives violate the natural meaning of "competition," that each participant in the market is so small that he believes that he will have no effect on the behavior of others (Rothschild and Stiglitz, 1997).

The new information paradigm went further in undermining the foundations of competitive equilibrium analysis, the basic "laws" of economics. For example, we have shown how,

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[12] In the natural "spaces," indifference curves and isoprofit curves were ill behaved. The nonconvexities which naturally arose implied, in turn, that equilibrium might be characterized by randomization (Stiglitz, 1975b), or that Pareto-efficient tax and optimal tax policies might be characterized by randomization (see Stiglitz [1982g], Arnott and Stiglitz [1988a], and Dagobert L. Brito et al. [1995]). Even small fixed costs (of search, of finding out about characteristics of different investments, of obtaining information about relevant technology) imply that markets will not be *perfectly* competitive; they will be better described by models of *monopolistic competition* (see Avinash K. Dixit and

Stiglitz [1977], Steven Salop [1977], and Stiglitz [1979a, b, 1989f]), though the basis of imperfect competition was markedly different from that originally envisioned by Edward H. Chamberlin (1933).

[13] Nonconvexities naturally give rise to discontinuities, and discontinuities to problems of existence, but the nonexistence problem that Rothschild and I had uncovered was of a different, and more fundamental nature. The problem was in part that a single action of an individual—a choice of one insurance policy over another—discretely changed beliefs, e.g., about his type; and that a slight change in the actions of, say an insurance firm—making available a new insurance policy—could lead to discrete changes in actions, and thereby beliefs. Partha Dasgupta and Eric Maskin (1986) have explored mixed strategy equilibria in game-theoretic formulations, but these seem less convincing than the imperfect competition resolutions of the existence problems described below. I explored other problems of nonexistence in the context of moral hazard problems in work with Richard Arnott (1987, 1991b).

[14] This had a particularly inconvenient implication: when there was a continuum of types, such as in the A. Michael Spence (1973, 1974) models, a full equilibrium never existed.

when prices affect "quality"—either because of incentive or selection effects—equilibrium may be characterized by demand not equaling supply; firms will not pay lower wages to workers, even when they can obtain such workers, because doing so will raise their labor costs. Contrary to the law of one price, we have shown that the market will be characterized by wage and price distributions, even when there is no exogenous source of "noise" in the economy, and even when all firms and workers are (otherwise) identical. Contrary to standard competitive results, we have shown that in equilibrium, firms may charge a price in excess of the marginal costs, or workers may be paid a wage in excess of their reservation wage, so that the incentive to maintain a reputation is maintained (see also Benjamin Klein and Keith B. Leffler, 1981; Shapiro, 1983). Contrary to the efficient markets hypothesis (Eugene F. Fama, 1970), which holds that stock prices convey all the relevant information from the informed to the uninformed, Sanford J. Grossman and I (1976, 1980a) showed that, when information is costly to collect, stock prices necessarily aggregate information imperfectly (to induce people to gather information, there must be an "equilibrium amount of disequilibrium"). Each of these cornerstones of the competitive paradigm was rejected, or was shown to hold only under much more restrictive conditions.

The most fundamental reason that markets with imperfect information differ from those in which information is complete is that, with imperfect information, market actions or choices convey information. Market participants know this and respond accordingly. For example, firms provide guarantees not only because they are better able to absorb the risk of product failure but to convey information about their confidence in their products. A person takes an insurance policy with a large deductible to convey to the insurer his belief that the likelihood of his having an accident is low. Information may also be concealed: A firm may not assign an employee to a highly visible job, because it knows that the assignment will be interpreted as an indication that the employee is good, making it more likely that a rival will try to hire the person away.

One of the early insights (Akerlof, 1970) was that, with imperfect information, markets may be thin or absent. The absence of particular

markets, e.g., for risk, has profound implications for how *other* markets function. The fact that workers and firms cannot buy insurance against many of the risks which they face affects labor and capital markets; it leads, for instance, to labor contracts in which the employer provides *some* insurance. But the design of these more complicated, but still imperfect and incomplete, contracts affects the efficiency, and overall performance, of the economy.

Perhaps most importantly, under the standard paradigm, markets are Pareto efficient, except when one of a limited number of market failures occurs. Under the imperfect information paradigm, markets are almost never Pareto efficient.

While information economics thus undermined these long-standing principles of economics, it also provided explanations for many phenomena that had long been unexplained. Before turning to these applications, I want to present a somewhat a more systematic account of the *principles* of the economics of information.

A. *Some Problems in Constructing an Alternative Paradigm*

The fact that information is imperfect was, of course, well recognized by all economists. The reason that models with imperfect information were not developed earlier was that it was not obvious how to do so: While there is a single way in which information is perfect, there are an infinite number of ways in which information can be imperfect. One of the keys to success was formulating simple models in which the set of relevant information could be fully specified— and so the precise ways in which information was imperfect could also be fully specified. But there was a danger in this methodology, as useful as it was: In these overly simplistic models, full revelation of information was sometimes possible. In the real world, of course, this never happens, which is why in some of the later work (e.g., Grossman and Stiglitz, 1976, 1980a), we worked with models with an infinite number of states. Similarly there may well be ways of fully resolving incentive problems in simple models, which collapse when models are made more realistic, for example by combining selection and incentive problems (Stiglitz and Weiss, 1986).

Perhaps the hardest problem in building the new paradigm was modeling equilibrium. It was important to think about both sides of the market—employers and employees, insurance company and the insured, lender and borrower. Each had to be modeled as "rational," in some sense, making inferences on the basis of available information and behaving accordingly. I wanted to model *competitive* behavior, where each actor in the economy was small, and believed he was small—and so his actions could not or would not affect the equilibrium (though others' inferences about himself might be affected). Finally, one had to think carefully about what was the feasible set of actions: what might each side do to extract or convey information to others.

As we shall see, the variety of results obtained (and much of the confusion in the early literature) arose partly from a failure to be as clear as one might have been about the assumptions. For instance, the standard adverse selection model had the quality of the good offered in the market (say of used cars, or riskiness of the insured) depending on price. The car buyer (the seller of insurance) knows the *statistical* relationship between price and quality, and this affects his demand. The market equilibrium is the price at which demand equals supply. But that is an equilibrium if and only if there is no way by which the seller of a good car can convey that information to the buyer—so that he can earn a quality premium—and if there is no way by which the buyer can sort out good cars from bad cars. Typically, there are such ways, and it is the attempt to elicit that information which has profound effects on how markets function. To develop a new paradigm, we had to break out from long-established premises, to ask what should be taken as assumptions and what should be derived from the analysis. Market clearing could not be taken as an assumption; neither could the premise that a firm sells a good at a particular price to all comers. One could not *begin* the analysis even by assuming that in competitive equilibrium there would be zero profits. In the standard theory, if there were positive profits, a firm might enter, bidding away existing customers. In the new theory, the attempt to bid away new customers by slightly lowering prices might lead to marked changes in their behavior or in the mix of customers, in such a way that the profits of the new entrant actually became negative. One had to rethink all the conclusions from first premises.

We made progress in our analyses because we began with highly simplified models of particular markets, that allowed us to think through carefully each of the assumptions and conclusions. From the analysis of particular markets (whether the insurance market, the education market, the labor market, or the land tenancy/sharecropping market), we attempted to identify general principles, to explore how these principles operated in each of the other markets. In doing so, we identified particular features, particular informational assumptions, which seemed to be more relevant in one market or another. The nature of competition in the labor market is different from that in the insurance market or the capital market, though these markets have much in common. This interplay, between looking at the ways in which such markets are similar and dissimilar, proved to be a fruitful research strategy.[15]

B. *Sources of Information Asymmetries*

Information imperfections are pervasive in the economy: indeed, it is hard to imagine what a world with perfect information would be like. Much of the research I describe here focuses on *asymmetries* of information, that fact that different people know different things. Workers know more about their own abilities than the firm does; the person buying insurance knows more about his health, e.g., whether he smokes and drinks immoderately, than the insurance

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[15] Some earlier work, especially in general-equilibrium theory, by Leonid Hurwicz (1960, 1972), Jacob Marschak and Radner (1972), and Radner (1972), among others, had recognized the importance of problems of information, and had even identified some of the ways that limited information affected the nature of the market equilibrium (e.g., one could only have contracts that were contingent on states of nature that were observable by both sides to the contract). But the attempt to modify the abstract theory of general equilibrium to incorporate problems of information imperfects proved, in the end, less fruitful than the alternative approach of beginning with highly simplified, quite concrete models. Arrow (1963, 1965, 1973, 1974, 1978), while a key figure within the general-equilibrium approach, was one of the first to identify the importance of adverse selection and moral hazard effects.

firm. Similarly, the owner of a car knows more about the car than potential buyers; the owner of a firm knows more about the firm that a potential investor; the borrower knows more about the riskiness of his project than the lender does; and so on.

An essential feature of a decentralized market economy is that different people know different things, and in some sense, economists had long been thinking of markets with information asymmetries. But the earlier literature had neither thought about how these were created, or what their consequences might be. While such information asymmetries inevitably arise, the extent to which they do so and their consequences depend on how the market is structured, and the recognition that they will arise affects market behavior. For instance, even if an individual has no more information about his ability than potential employers, the moment he goes to work for a specific employer, an information asymmetry has been created—the employer may now know more about the individual's ability than others do. A consequence is that the "used labor" market may not work well. Other employers will be reserved in bidding for the worker's services, knowing that they will succeed in luring him away from his current employer only if they bid too much. This impediment to labor mobility gives market power to the first employer, which he will be tempted to exercise. But then, because a worker knows he will tend to be locked into a job, he will be more risk averse in accepting an offer. The terms of the initial contract thus have to be designed to reflect the diminution of the worker's bargaining power that occurs the moment he accepts a job.

To take another example, it is natural that in the process of oil exploration, a company may obtain information relevant to the likelihood that there will be oil in a neighboring tract—an informational externality (see Stiglitz, 1975d; Jeffrey J. Leitzinger and Stiglitz, 1984). The existence of this asymmetric information affects the nature of the bidding for oil rights on the neighboring tract. Bidding when there is known to be asymmetries of information will be markedly different from that where such asymmetries do not exist (Robert B. Wilson, 1977). Those who are uninformed will presume that they will win only if they bid too much—information asymmetries exacerbate the prob-

lem of the "winner's curse" (Wilson, 1969; Edward Capen et al., 1971). The government (or other owners of large tracts to be developed) should take this into account in its leasing strategy. And the bidders in the initial leases too will take this into account: part of the value of winning in the initial auction is the information rent that will accrue in later rounds.

While early work in the economics of information dealt with how markets overcame problems of information asymmetries, later work turned to how actors in markets *create* information problems, for example in an attempt to exploit market power. An example is managers of firms who attempt to entrench themselves, and reduce competition in the market for managers, by taking actions to increase information asymmetry (Andrei Shleifer and Robert W. Vishny, 1989; Aaron S. Edlin and Stiglitz, 1995). This is an example of the general problem of corporate governance, to which I will return later. Similarly, the presence of information imperfections give rise to market power in product markets. Firms can exploit this market power through "sales" and other ways of differentiating among individuals who have different search costs (Salop, 1977; Salop and Stiglitz, 1977, 1982; Stiglitz, 1979a). The price dispersions which exist in the market are *created* by the market—they are not just the failure of markets to arbitrage fully price differences caused by shocks that affect different markets differently.

C. Overcoming Information Asymmetries

I now want to discuss briefly the ways by which information asymmetries are dealt with, how they can be (partially) overcome.

1. *Incentives for Gathering and Disclosing Information.*—There are two key issues: what are the *incentives* for obtaining information, and what are the *mechanisms*. My brief discussion of the analysis of education as a screening device suggested the fundamental incentive: More able individuals (lower risk individuals, firms with better products) will receive a higher wage (will have to pay a lower premium, will receive a higher price for their products) if they can establish that they are more productive (lower risk, higher quality).

We noted earlier that while some individuals have an incentive to disclose information, some have an incentive not to have the information disclosed. Was it possible that in market equilibrium, only *some* of the information would be revealed? One of the early important results was that, if the more able can costlessly establish that they are more able, then the market will be fully revealing, even though those who are below average would prefer that no information be revealed. In the simplest models, I described a process of unraveling: If the most able could establish his ability, he would; but then all but the most able would be grouped together, receiving the mean marginal product of that group; and the most able of that group would have an incentive to reveal his ability. And so on down the line, until there was full revelation. (I jokingly referred to this as "Walras' Law of Sorting"—if all but one group sorts itself out from the others, then the last group is also identified.)

What happens if those who are more able cannot credibly convince potential employers of their ability? The other side of the market has an incentive too to gather information. An employer that can find a worker that is better than is recognized by others will have found a bargain, because the worker's wage will be determined by what others think of him. The problem, as we noted, is that if what the employer knows becomes known to others, the worker's wage will be bid up, and the employer will be unable to appropriate the returns on his investment in information acquisition.

The fact that competition makes it difficult for the screener to appropriate the returns from screening has an important implication: In markets where, for one reason or another, the more able cannot fully convey their attributes, investment in screening requires *imperfect competition in screening*. The economy, in effect, has to choose between two different imperfections: imperfections of information or imperfections of competition. Of course, in the end, there will be both forms of imperfection, and no particular reason that these imperfections will be "balanced" optimally (Stiglitz, 1975b; Dwight Jaffee and Stiglitz, 1990). This is but one of many examples of the *interplay* between market imperfections. Earlier, for instance, we discussed the incentive problems associated with

sharecropping, which arise when workers do not own the land that they till. This problem could be overcome if individuals could borrow to buy their land. But capital market imperfections—limitations on the ability to borrow, which themselves arise from information imperfections—explain why this "solution" does not work.

There is another important consequence: if markets were fully informationally efficient—that is, if information disseminated instantaneously and perfectly throughout the economy—then no one would have any incentive to gather information, so long as there was any cost of doing so. Hence markets cannot be fully informationally efficient (Grossman and Stiglitz, 1976, 1980a).

2. *Mechanisms for Elimination of Reducing Information Asymmetries.*——In simple models where (for example) individuals know their own abilities there might seem an easy way to resolve the problem of information asymmetry: Let each person tell his true characteristic. Unfortunately, individuals do not necessarily have the incentive to tell the truth. Talk is cheap. Other methods must be used to convey information credibly.

The simplest way by which that could be done was an exam. Models of competitive equilibrium (Arrow, 1973; Stiglitz, 1974a) with exams make two general points. First, in equilibrium *the gains of the more able were largely at the expense of the less able.* Establishing that an individual is of higher ability provides that person with higher wages, but simultaneously establishes that others are of lower ability. Hence the private returns to expenditures on educational screening exceed the social returns. It was clear that there were important *externalities* associated with information, a theme which was to recur in later work. Second, and a more striking result, there could exist multiple equilibria—one in which information was fully revealed (the market identified the high and low ability people) and another in which it was not (called a pooling equilibrium). The pooling equilibrium Pareto-dominated the equilibrium with full revelation. This work, done some 30 years ago, established two results of great policy import, which remarkably have not been fully absorbed into policy discussions

even today. First, markets do not provide appropriate incentives for information disclosure. There is, in principle, a role for government. And second, expenditures on information may be too great (see also Hirshleifer, 1971).

3. *Conveying Information Through Actions.*——But much of the information firms glean about their employees, banks about their borrowers, or insurance companies about their insured, comes not from examinations but from making inferences based on their *behavior*. This is a commonplace in life—but it was not in our economic models. As I have already noted, the early discussions of adverse selection in insurance markets recognized that as an insurance company raised its premiums, those who were least likely to have an accident might decide not to purchase the insurance; the willingness to purchase insurance at a particular price conveyed information to the insurance company. George Akerlof recognized that this phenomenon is far more general: the owner's willingness to sell a used car, for instance, conveyed information about the car's quality.

Bruce C. Greenwald (1979, 1986) took these ideas one important step further, showing how adverse selection applied to labor and capital markets (see also Greenwald et al., 1984; Stewart C. Myers and Nicholas S. Majluf, 1984). For example, the willingness of insiders in a firm to sell stock at a particular price conveys information about their view of what the stock is really worth. Akerlof's insight that the result of these information asymmetries was that markets would be thin or absent helped explain why labor and capital markets often did not function well. It provided part of the explanation for why firms raised so little of their funds through equity (Mayer, 1990). Stigler was wrong: imperfect information was not just like a transactions cost.

There is a much richer set of actions which convey information beyond those on which traditional adverse selection models have focused. An insurance company wants to attract healthy applicants. It might realize that by locating itself on the fifth floor of a walk-up building, only those with a strong heart would apply. The willingness or ability to walk up five floors conveys information. More subtly, it might recognize that how far up it needs to

locate itself, if it only wants to get healthy applicants, depends on other elements of its strategy, such as the premium charged. Or the company may decide to throw in a membership in a health club, but charge a higher premium. Those who value a health club—because they will use it—willingly pay the higher premium. But these individuals are likely to be healthier.

There are a host of other actions which convey information. The quality of the guarantee offered by a firm can convey information about the quality of the product; only firms that believe that their product is reliable will be willing to offer a good guarantee. The guarantee is desirable not just because it reduces risk, but because it conveys information. The number of years of schooling may convey information about the ability of an individual. More able individuals may go to school longer, in which case the increase in wages associated with an increase in schooling may not be a consequence of the human capital that has been added, but rather simply be a result of the sorting that occurs. The size of the deductible that an individual chooses in an insurance policy may convey information about his view about the likelihood of an accident or the size of the accidents he anticipates—*on average,* those who are less likely to have an accident may be more willing to accept high deductibles. The willingness of an entrepreneur to hold large fractions of his wealth in a firm (or to retain large fractions of the shares of the firm) conveys information about his beliefs in the firm's future performance. If a firm promotes an individual to a particular job, it may convey information about the firm's assessment of his ability.

The fact that these actions may convey information affects behavior. In some cases, the action will be designed to obfuscate, to limit information disclosure. The firm that knows that others are looking at who it promotes, and will compete more vigorously for those workers, may affect the willingness of the firm to promote some individuals or assign them to particular jobs (Michael Waldman, 1984). In others, the action will be designed to convey information in a credible way to alter beliefs. The fact that customers will treat a firm that issues a

better guarantee as if its product is better—and therefore be willing to pay a higher price—may affect the guarantee that the firm is willing to issue. Knowing that selling his shares will convey a negative signal concerning his views of the future prospects of his firm, an entrepreneur may retain more of the shares of the firm; he will be less diversified than he otherwise would have been (and accordingly, he may act in a more risk-averse manner).

A simple lesson emerges: Some individuals wish to convey information; some individuals wish not to have information conveyed (either because such information might lead others to think less well of them, or because conveying information may interfere with their ability to appropriate rents). In either case, the fact that actions convey information leads people to alter their behavior, and changes how markets function. This is why information imperfections have such profound effects.

Once one recognizes that actions convey information, two results follow. First, in making decisions about what to do, individuals will not only think about what they like (as in traditional economics) but how it will affect others' beliefs about them. If I choose to go to school longer, it may lead others to believe that I am more able. I may therefore decide to stay in school longer, not because I value what is being taught, but because I value how it changes others' beliefs concerning my ability. This means, of course, that we have to rethink completely firm and household decision-making.

Secondly, we noted earlier that individuals have an incentive to "lie"—the less able to say that they are more able. Similarly, if it becomes recognized that those who walk up to the fifth floor to apply for insurance are more healthy, then I might be willing to do so even if I am not so healthy, simply to fool the insurance company. Recognizing this, one needs to look for ways by which information is conveyed *in equilibrium.* The critical insight in how that could occur was provided in a paper I wrote with Michael Rothschild (1976). If those who were more able, less risk prone, or more creditworthy *acted* in some observable way (had different preferences) than those who were less able, less risk prone, or less creditworthy, then it might be possible to design a set of *choices,* which would

result in those with different characteristics in effect *identifying* themselves through their *self-selection.* The particular mechanism which we explored in our insurance model illustrates how self-selection mechanisms work. People who know they are less likely to have an accident will be more willing to accept an insurance policy with a high deductible, so that an insurance company that offered two policies, one at a high premium and no deductible, one with a low premium and high deductible, would be able to sort out who were high risk and who low. It is an easy matter to construct choices which thus *separate* people into classes.

It was clear that information was conveyed because the actions were costly, and more costly for some than others. The attempt to convey information had to *distort* behavior. Our analysis also made it clear that it was not just information asymmetries, but information imperfections more generally, that were relevant. Even if those buying insurance did not know their accident probabilities (or know them with greater accuracy than the insurance company), so long as those with higher accident probabilities *on average* differed in some way reflected in their preferences and actions, self-selection mechanisms could and would be employed to sort.

Yet another set of issues arise from the fact that actions may not be costlessly observable. The employer would like to know how hard his worker is working; the lender would like to know the actions which borrower will undertake. These asymmetries of information about *actions* are as important as the earlier discussed asymmetries. Just as in the adverse selection model, the seller of insurance may try to overcome the problems posed by information asymmetries by *examination,* so too in the moral hazard or adverse incentive model, he may try to *monitor* the actions of the insured. But examinations and monitoring are costly, and while they yield some information, typically there remains a high level of residual information imperfection. One response to this problem is to try to induce desired behavior through the setting of contract terms. For example, borrowers' risk-taking behavior may be affected by the interest rate charged by the lender (Stiglitz and Weiss, 1981).

D. Consequences for Market Equilibrium

The law of supply and demand had long been treated as a fundamental principle of economics. But there is in fact no law that requires the insurance firm to sell to all who apply at the announced premium, or the lender to lend to all who apply at the announced interest rate, or the employer to employ all those who apply at the posted wage. With perfect information and perfect competition, any firm that charged a price higher than the others would lose all of its customers; and at the going price, one faced a perfectly elastic supply of customers. In adverse selection and incentive models, what mattered was not just the supply of customers or employees or borrowers, but their "quality"—the riskiness of the insured or the borrower, the returns on the investment, the productivity of the worker.

Since "quality" may increase with price, it may be profitable (for example) to pay a higher wage than the "market-clearing" wage, whether the dependence on quality arises from adverse selection or adverse incentive effects (or, in the labor market, because of morale or nutritional effects). The consequence, as we have noted, is that market equilibrium may be characterized by demand not equaling supply in the traditional sense. In credit market equilibrium, the supply of loans may be rationed (William R. Keeton, 1979; Jonathan Eaton and Mark Gersovitz, 1981; Stiglitz and Weiss, 1981). Or, in the labor market, the wage rate may be higher than that at which the demand for labor equals the supply (an efficiency wage), leading to unemployment.[16]

Analyzing the choices which arise in *full* equilibrium, taking into account fully not only the knowledge that the firms have, say, about their customers but also the knowledge that customers have about how firms will make inferences about them from their behavior, and taking into account the fact that the inferences that a firm might make depends not only on what that firm does, but also on what other firms do, turned out, however, to be a difficult task. The easiest situation to analyze was that of a monopolist (Stiglitz, 1977). The monopolist could construct a set of choices that would *differentiate* among different types of individuals, and analyze whether it was profit maximizing for him to do so fully, or to (partially) "pool"—that is, offer a set of contracts such that several types might choose the same one. This work laid the foundations of a *general theory of price discrimination.* Under standard theories of monopoly, with perfect information, firms would have an incentive to price discriminate perfectly (extracting the full consumer surplus from each). If they did this, then monopoly would in fact be nondistortionary. Yet most models assumed no price discrimination (that is, the monopolist offered the same price to all customers), without explaining why they did not do so. The new work showed how, given limited information, firms could price discriminate, but could do so only imperfectly. Subsequent work by a variety of authors (such as William J. Adams and Yellen, 1976; Salop, 1977) explored ways by which a monopolist might find out relevant characteristics of his customers. Information economics thus provided the first coherent theory of monopoly.

The reason that analyzing monopoly was easy is that the monopolist could structure the entire choice set facing his customers. The hard question is to describe the full competitive equilibrium, e.g., a set of insurance contracts such that no one can offer an alternative set that would be profitable. Each firm could control the choices that it offered, but not the choices offered by others; and the decisions made by customers depended on the entire set of choices available. In our 1976 paper, Rothschild and I succeeded in analyzing this case.

Three striking results emerged from this analysis. The first I have already mentioned: Under plausible conditions, given the natural definition of equilibrium, equilibrium might not exist. There were two possible forms of equilibria: *pooling equilibria,* in which the market is not able to distinguish among the types, and *separating equilibria,* in which it is. The different groups "separate out" by taking different actions. We showed in our context that there never

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[16] Constructing *equilibrium models* with these effects is more difficult than might seem to be the case at first, since each agent's behavior depends on opportunities elsewhere, i.e., the behavior of others. For example, the workers that a firm attracts at a particular wage depend on the wage offers of other firms. Shapiro and Stiglitz (1984), Rodríguez and Stiglitz (1991a, b), and Rey and Stiglitz (1996), represent attempts to come to terms with these general-equilibrium problems.

could be a pooling equilibrium—if there were a single contract that everyone bought, there was another contract that another firm could offer which would "break" the pooling equilibrium. On the other hand, there might not exist a separating equilibrium either, if the cost of separation was too great. Any putative separating equilibrium could be broken by a profitable pooling contract, a contract which would be bought by both low risk and high risk types.[17]

Second, even small amounts of imperfections of information can change the standard results concerning the existence and characterization of equilibrium. Equilibrium, for instance, never exists when the two types are very near each other. As we have seen, the competitive equilibrium model is simply not robust.

Third, we now can see how the fact that actions convey information affects equilibrium. In perfect information models, individuals would fully divest themselves of the risks which they face, and accordingly would act in a risk neutral manner. We explained why insurance markets would not work well—why most risk-averse individuals would buy only partial insurance. The result was important not only for the insights it provided into the workings of insurance markets, but because there are important elements of insurance in many transactions and markets. The relationship between the landlord and his tenant, or the employer and his employee, contains an insurance component.

In short, the general principle that actions convey information applies in many contexts. Further, limitations on the ability to divest oneself of risk are important in explaining a host of contractual relationships.

E. *Sorting, Screening, and Signaling*

In equilibrium, both buyers and sellers, employers and employees, insurance company and insured, and lender and creditor are aware of the informational consequences of their actions. In the case where, say, the insurance company or employer takes the initiative in sorting out applicants, self-selection is an alternative to examinations as a sorting device. In the case where the insured, or the employee, takes the initiative to identify himself as a more attractive contractual partner, then it is conventional to say he is *signaling* (Spence, 1973). But of course, in equilibrium both sides are aware of the consequences of alternative actions, and the differences between signaling and self-selection screening models lie in the technicalities of game theory, and in particular whether the informed or uninformed player moves first.[18]

Still, some of the seeming differences between signaling and screening models arise because of a failure to specify a *full* equilibrium. We noted earlier that there might be many separating contracts, but a unique separating equilibrium. We argued that if one considered any other separating set of contracts, then (say, in the insurance market) a firm could come in and offer an alternative set of contracts and make a profit. Then the original set of separating contracts could not have been an equilibrium. The same is true in, say, the education signaling model. There are many educational systems which "separate"—that is, the more able choose to go to school longer, and the wages at each level of education correspond to the productivity of those who go to school for that length of time. But all except one are not *full equilibria*. Assume, for instance, there were two types of individuals, of low ability and of high ability. Then if the low-ability person has 12 years of schooling, then any education system in which the high-ability person went to school sufficiently long—say, more than 14 years—might separate. But the low-ability types would rec-

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[17] Of course, insurance markets do exist in the real world. I suspect that a major limitation of the applicability of Rothschild-Stiglitz (1976) is the assumption of perfect competition. Factors such as search costs and uncertainty about how easy it is to get a company to pay a claim make the assumption of perfect competition less plausible. Self-selection is still relevant, but some version of monopolistic competition, may be more relevant than the model of perfect competition.

[18] See, in particular, Stiglitz and Weiss (1983a, 1994) and Shiro Yabushita (1983). As we point out, in the real world, who moves first ought to be viewed as an endogenous variable. In such a context, it appears that the screening equilibria are more robust than the signaling equilibrium. Assume, for instance, that there were some signaling equilibrium that differed from the screening equilibrium, e.g., there were a pooling equilibrium, sustained because of the out-of-equilibrium beliefs of firms. Then such an equilibrium could be broken by a prior or later move of firms.

ognize that if they went to school for 11 years, they would still be treated as having low ability. The unique equilibrium level of education for the low-ability person is that which maximizes his net income (taking into account the productivity gains and costs of education). The unique equilibrium level of education for the high-ability type is the lowest level of education such that the low-ability type does not have the incentive to mimic the high-ability person's educational attainment.

The education system, of course, was particularly infelicitous for studying *market* equilibrium. The structure of the education system is largely a matter of public choice, not of market processes. Different countries have chosen markedly different systems. The minimum level of education is typically not a matter of choice, but set by the government. Within educational systems, examinations play as important a role as self-selection or signaling, though *given* a certain standard of testing, there is a process of self-selection involved in deciding whether to stay in school, or to try to pass the examination. For the same reason, the problems of existence which arise in the insurance market are not relevant in the education market—the "competitive" supply side of the market is simply absent. But when the signaling concepts are translated into contexts in which there is a robust competitive market, the problems of existence cannot be so easily ignored. In particular, when there is a continuum of types, as in the Spence (1973) model, there never exists a screening equilibrium.

F. *Equilibrium Contracts*

The work with Rothschild was related to earlier work that I had done on incentives (such as the work on sharecropping) in that both lines of work entailed an "equilibrium in contracts." The contracts that had characterized economic relations in the standard competitive model were extraordinarily simple: I will pay you a certain amount if you do such and such. If you did not perform as promised, the pay was not given. But with perfect information, individuals simply would not sign contracts that they did not intend to fulfill. Insurance contracts were similarly simple: A payment occurred if and only if particular specified events occurred.

The work on sharecropping and on equilibrium with competitive insurance markets showed that with imperfect information, a far richer set of contracts would be employed and thus began a large literature on the theory of contracting. In the simple sharecropping contracts of Stiglitz (1974b), the contracts involved shares, fixed payments, and plot sizes. More generally, optimal payment structures related payments to *observables,* such as inputs, processes, or outputs.[19] Further, because what goes on in one market affects other parts of the economy, the credit, labor, and land markets are *interlinked;* one could not decentralize in the way hypothesized by the standard perfect information model. (Avishay Braverman and Stiglitz, 1982, 1986a, b, 1989).

These basic principles were subsequently applied in a variety of other market contexts. The most obvious was the design of labor contracts (Stiglitz, 1975a). Payments to workers can depend not only on output, but on *relative* performance, which may convey more relevant information than absolute performance. For example, the fact that a particular company's stock goes up when all other companies' stock goes up may say very little about the performance of the manager. Nalebuff and Stiglitz (1983a, b) analyzed the design of these relative performance compensation schemes (contests).

Credit markets too are characterized by complicated equilibrium contracts. Lenders may specify not only an interest rate, but also impose other conditions (collateral requirements, equity requirements) which would have both incentive and selection effects.[20] Indeed, the simultaneous presence of both selection and incentive

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[19] In Stiglitz (1974b) the contracts were highly linear. In principle, generalizing payment structures to nonlinear functions was simple. Though even here, there were subtleties, e.g., whether individuals exerted their efforts before they knew the realization of the state of nature, and whether there were bounds on the penalties that could be imposed, in the event of bad outcomes (James A. Mirrlees [1975b]; Stiglitz [1975a]; Mirrlees [1976]). The literature has not fully resolved the reason that contracts are often much simpler than the theory would have predicted (e.g., payments are linear functions of output), and do not adjust to changes in circumstances (see, e.g., Franklin Allen, 1985; Douglas Gale, 1991).

[20] See, for instance, Stiglitz and Weiss (1983b, 1986, 1987). Even with these additional instruments there could still be nonmarket-clearing equilibria.

effects is important in credit markets. In the absence of the former, it might be possible to increase the collateral requirement *and* raise interest rates, still ensuring that the borrower undertook the safe project.

As another application, "contracting"—including provisions that help information be conveyed and risks be shared—have been shown to play an important role in explaining macroeconomic rigidities. See, for instance, Costas Azariadis and Stiglitz (1983), the papers of the symposium in the 1983 *Quarterly Journal of Economics,* the survey article by Sherwin Rosen (1985), Arnott et al. (1988), and Lars Werin and Hans Wijkander (1992). Moreover, problems of asymmetries of information can help explain the perpetuation of seemingly inefficient contracts. (Stiglitz, 1992b).

G. *Equilibrium Wage and Price Distributions*

One of the most obvious differences between the predictions of the model with perfect information and what we see in everyday life is the conclusion that the same good sells for the same price everywhere. In reality, we all spend a considerable amount of time shopping for good buys. The differences in prices represent more than just differences in quality or service. There are *real* price differences. Since Stigler's classic paper (1961), there has been a large literature exploring optimal search behavior. However Stigler, and most of the search literature, took the price or wage distribution as given. They did not ask how the distribution might arise and whether, given the search costs, it could be sustained.

As I began to analyze these models, I found that there could be a nondegenerate equilibrium wage or price distribution even if all agents were identical, e.g., faced the same search costs. Early on, it had become clear that even small search costs could make a large difference to the behavior of product and labor markets. Peter A. Diamond (1971) had independently made this point in a highly influential paper, which serves to illustrate powerfully the lack of robustness of the competitive equilibrium theory. Assume for example, as in the standard theory, that all firms were charging the competitive price, but there is an epsilon cost of searching, of going to another store. Then any firm which charged half an

epsilon more would lose no customers and thus would choose to increase its price. Similarly, it would pay all other firms to increase their prices. But at the higher price, it would again pay each to increase price, and so on until the price charged at every firm is the monopoly price, even though search costs are small. This showed convincingly that the competitive price was not the equilibrium. But in some cases, not even the monopoly price was an equilibrium. In general, Salop and Stiglitz (1977, 1982, 1987) and Stiglitz (1979b, 1985c, 1987b, 1989c) showed that in situations where there were even small search costs, markets might be characterized by a price distribution. The standard wisdom that said that not everyone had to be informed to ensure that the market acted perfectly competitive was simply not, in general, true (see Stiglitz, 1989c, for a survey).

IV. Efficiency of the Market Equilibrium and the Role of the State

The fundamental theorems of neoclassical welfare economics state that competitive economies will lead, as if by an invisible hand, to a (Pareto-) efficient allocation of resources, and that every Pareto-efficient resource allocation can be achieved through a competitive mechanism, provided only that the appropriate lump-sum redistributions are undertaken. These theorems provide both the rationale for the reliance on free markets, and for the belief that issues of distribution can be separated from issues of efficiency, allowing the economist the freedom to push for reforms which increase efficiency, regardless of their seeming impact on distribution. (If society does not like the distributional consequences of a policy, it should simply redistribute income.)

The economics of information showed that neither of these theorems was particularly relevant to real economies. To be sure, economists over the preceding three decades had identified important market failures—such as the externalities associated with pollution—which required government intervention. But the scope for market failures was limited, and thus the arenas in which government intervention was required were correspondingly limited.

Early work, already referred to, had laid the foundations for the idea that economies with

information imperfections would not be Pareto efficient, *even taking into account the costs of obtaining information.* There were interventions in the market that could make all parties better off. We had shown, for instance, that incentives for the disclosure and acquisition of information were far from perfect. On the one hand, imperfect appropriability meant that there might be insufficient incentives to gather information; but on the other, the fact that much of the gains were "rents," gains by some at the expense of others, suggested that there might be excessive expenditures on information. A traditional argument for unfettered capital markets was that there are strong incentives to gather information; discovering that some stock was more valuable than others thought would be rewarded by a capital gain. This price discovery function of capital markets was often advertised as one of its strengths. But while the individual who discovered the information a nanosecond before anyone else might be better off, was society as a whole better off? If having the information a nanosecond earlier did not lead to a change in real decisions (e.g., concerning investment), then it was largely redistributive, with the gains of those obtaining the information occurring at the expense of others (Stiglitz, 1989c).

There are potentially other inefficiencies associated with information acquisition. Information can have adverse effects on volatility (Stiglitz, 1989i). And information can lead to the destruction of markets, in ways which lead to adverse effects on welfare. For example, individuals may sometimes have incentives to create information asymmetries in insurance markets, which leads to the destruction of those markets and a lowering of overall welfare. Welfare might be increased if the acquisition of this kind of information could be proscribed. Recently, such issues have become sources of real policy concern in the arena of genetic testing. Even when information is available, there are issues concerning its use, with the use of certain kinds of information having either a discriminatory intent or effect, in circumstances in which such direct discrimination itself would be prohibited.[21]

While it was perhaps not surprising that markets might not provide appropriate incentives for the acquisition and dissemination of information, the market failures associated with imperfect information may be far more profound. The intuition can be seen most simply in the case of models with moral hazard. There, the premium charged is associated with the *average* risk and, therefore, the average care, taken by seemingly similar individuals. The moral hazard problem arises because the level of care cannot be observed. Each individual ignores the effect of his actions on the premium; but when they all take less care, the premium increases. The lack of care by each exerts a negative externality on others. The essential insight of Greenwald and Stiglitz (1986)[22] was to recognize that such externality-like effects are pervasive whenever information is imperfect or markets incomplete—that is always—and as a result, markets are essentially never constrained Pareto efficient. In short, market failures are pervasive. Arnott et al. (1994) provide a simple exposition of this point using the standard self-selection and incentive compatibility constraints.

An important implication is that efficient allocations cannot in general be decentralized via competitive markets. The notion that one could decentralize decision-making to obtain (Pareto-) efficient resource allocation is one of the fundamental ideas in economics. Greenwald and Stiglitz (1986) showed that that was not possible in general. A simple example illustrates what is at issue. An insurance company cannot monitor the extent of smoking, which

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[21] See, e.g., Rothschild and Stiglitz (1982, 1997). For models of statistical discrimination and some of their implications, see Arrow (1972), Phelps (1972), and Stiglitz (1973a, 1974d). See also Stiglitz (1984a).

[22] Greenwald and Stiglitz (1986) focus on models with adverse selection and incentive problems. Greenwald and Stiglitz (1988a) showed that similar results hold in the context of search and other models with imperfect information. Earlier work, with Shapiro (1983) had shown, in the context of a specific model, that equilibria in an economy with an agency or principal-agent problem were not (constrained) Pareto efficient. Later work, with Arnott (1990), explored in more detail the market failures that arise with moral hazard. Earlier work had shown that with imperfect risk markets, themselves explicable by imperfections of information, market equilibrium was Pareto inefficient. See David M. G. Newbery and Stiglitz (1982, 1984) and Stiglitz (1972a, 1981, 1982b).

has an adverse effect on health. The government cannot monitor smoking any better than the insurance company, but it can impose taxes, not only on cigarettes, but also on other commodities which are complements to smoking (and subsidies on substitutes which have less adverse effects). See Arnott and Stiglitz (1991a) and Stiglitz (1989a, 1998b).

A related result from the new information economics is that issues of efficiency and equity cannot easily be delinked. For example, with imperfect information, a key source of market failure is *agency problems,* such as those which arise when the owner of land is different from the person working the land. The extent of agency problems depends on the distribution of wealth, as we noted earlier in our discussion of sharecropping. Moreover, the notion that one could separate out issues of equity and efficiency also rested on the ability to engage in lump sum redistributions. But as Mirrlees (1971) had pointed out, with imperfect information, this was not possible; all redistributive taxation must be distortionary. But this fact implies that interventions in the market which change the before-tax distribution of income could be desirable, because they lessened the burden on redistributive taxation (Stiglitz, 1998a). Again, the conclusion: The second welfare theorem, effectively asserting the ability to separate issues of distribution and efficiency, was not true.

In effect, the Arrow-Debreu model had identified the *single set* of assumptions under which markets were efficient. There had to be perfect information; more accurately, information could not be *endogenous,* it could not change either as a result of the actions of any individual or firm or through investments in information. But in the world we live in, a model which assumes that information is *fixed* seems irrelevant.

As the theoretical case that markets in which information is imperfect were not efficient became increasingly clear, several new arguments were put forward against government intervention. One we have already dealt with: that the government too faces informational imperfections. Our analysis had shown that the incentives and constraints facing government differed from those facing the private sector, so that even when government faced exactly the same *informational* constraints, welfare could be improved (Stiglitz, 1989a).

There was another rear-guard argument, which ultimately holds up no better. It is that market failures—absent or imperfect markets—give rise to nonmarket institutions. For example, the absence of death insurance gave rise to burial societies. Families provide insurance to their members against a host of risks for which they either cannot buy insurance, or for which the insurance premium is viewed as too high. But in what I call the *functionalist fallacy,* it is easy to go from the observation that an institution arises to fulfill a function to the conclusion that actually, *in equilibrium,* it serves that function. Those who succumbed to this fallacy seemed to argue that there was no need for government intervention because these nonmarket institutions would "solve" the market failure, or at least do as well as any government. Richard Arnott and I (1991a) showed that, to the contrary, nonmarket institutions could actually make matters worse. Insurance provided by the family could crowd out market insurance, for example. Insurance companies would recognize that the insured would take less risk because they had obtained insurance from others, and accordingly cut back on the amount of insurance that they offered. But since the nonmarket (family) institutions did a poor job of divesting risk, welfare could be decreased.

The Arnott-Stiglitz analysis reemphasized the basic point made at the end of the last subsection: it was only under very special circumstances that markets could be shown to be efficient. Why then should we expect an equilibrium involving nonmarket institutions and markets to be efficient?

V. Further Applications of the New Paradigm

Of all the market failures, the extended periods of underutilization of resources—especially human resources—is of the greatest moment. The consequences of unemployment are exacerbated in turn by capital market imperfections, which imply that even if the future prospects of an unemployed individual are good, he cannot borrow enough to sustain his standard of living.

We referred earlier to the dissatisfaction with traditional Keynesian explanations, in particular, the lack of microfoundations. This dissatis-

faction gave rise to two schools of thought. One sought to use the old perfect market paradigm, relying heavily on representative agent models. While information was not perfect, expectations were rational. But the representative agent model, by construction, ruled out the information asymmetries which are at the heart of macroeconomic problems. If one begins with a model that *assumes* that markets clear, it is hard to see how one can get much insight into unemployment (the failure of the labor market to clear).

The construction of a macroeconomic model which embraces the consequences of imperfections of information in labor, product, and capital markets has become one of my major preoccupations over the past 15 years. Given the complexity of *each* of these markets, creating a general-equilibrium model—simple enough to be taught to graduate students or used by policy makers—has not proven to be an easy task. At the heart of that model lies a new theory of the firm, for which the theory of asymmetric information provides the foundations. The modern theory of the firm in turn rests on three pillars, the theory of corporate finance, the theory of corporate governance, and the theory of organizational design.

A. *Theory of the Firm*

Under the older, perfect information theory (Franco Modigliani and Merton H. Miller, 1958, 1961; see also Stiglitz, 1969a, 1974c, 1988d), it made no difference whether firms raised capital by debt or equity, in the absence of tax distortions. But information is at the core of finance. The information required to implement equity contracts is greater than for debt contracts (Robert J. Townsend, 1979; Greenwald and Stiglitz, 1992). Most importantly, the willingness to hold (or to sell) shares conveys information (Hayne E. Leland and David H. Pyle, 1977; Ross, 1977; Stiglitz, 1982c; Greenwald et al., 1984; Myers and Majluf, 1984; Thomas F. Hellman and Stiglitz, 2000; for empirical verification see, e.g., Paul Asquith and David W. Mullins, Jr., 1986), so that how firms raise capital does make a difference. In practice, firms rely heavily on debt (as opposed to equity) finance (Mayer, 1990), and bankruptcy, resulting from the failure to meet debt obligations,

matters. Both because of the cost of bankruptcies and limitations in the design of managerial incentive schemes, firms act in a risk-averse manner—with risk being more than just correlation with the business cycle (Greenwald and Stiglitz, 1990a; Stiglitz, 1989g). Moreover, because of the potential for credit rationing, not only does the firm's net worth matter, but so does its asset structure, including its liquidity.[23]

While there are many implications of the theory of the risk-averse firm facing credit rationing, some of which are elaborated upon in the next section, one example should suffice to highlight the importance of these ideas. In traditional neoclassical investment theory, investment depends on the real interest rate and the firm's perception of expected returns. The firm's cash flow or its net worth should make no difference. The earliest econometric studies of investment, by Edwin Kuh and John R. Meyer (1957), suggested however that this was not the case. Nevertheless these variables were excluded from econometric analyses of investment for two decades following the work of Robert E. Hall and Dale W. Jorgenson (1967). It was not until work on asymmetric information had restored theoretical respectability that it became acceptable to introduce financial variables into investment regressions. When that was done, it was shown that—especially for small- and medium-sized enterprises—these variables are crucial. (For a survey of the vast empirical literature see R. Glenn Hubbard, 1998).

In the traditional theory, firms simply maximized the expected present discounted value of profits (which equaled market value); with perfect information, how that was to be done was simply an engineering problem. Disagreements about what the firm should do were of little moment. In that context, *corporate governance*—how firm decisions were made—mattered little as well. But again, in reality, corporate governance matters a great deal. There *are* disagreements about what the firm should do—partly motivated by differences in judgments, partly motivated by differences in objectives (Stiglitz,

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[23] The very concept of liquidity—and the distinction between lack of liquidity and insolvency—rests on information asymmetries. If there were perfect information, any firm that was liquid would be able to obtain finance, and thus would not face a liquidity problem.

1972b; Grossman and Stiglitz, 1977, 1980b). Managers can take actions which advance their interests at the expense of that of shareholders, and majority shareholders can advance their interests at the expense of minority shareholders. The owners not only could not monitor their workers and managers, because of asymmetries of information, they typically did not even know what these people who were supposed to be acting on their behalf *should* do. That there were important consequences for the theory of the firm of the separation of ownership and control had earlier been noted by Adolph A. Berle and Gardiner C. Means (1932), but it was not until information economics that we had a coherent way of thinking about the implications (Jensen and Willima H. Meckling, 1976; Stiglitz, 1985a).

Some who still held to the view that firms would maximize their market value argued that (the threat of) takeovers would ensure competition in the market for managers and hence promote stock market value maximization. If the firm were not maximizing its stock market value, then it would pay someone to buy the firm, and change its actions so that its value would increase. Early on in this debate, I raised questions on theoretical grounds about the efficacy of the takeover mechanism (Stiglitz, 1972b). The most forceful set of arguments were subsequently put forward by Grossman and Hart (1980), who observed that any small shareholder who believed that the takeover would subsequently increase market value would not be willing to sell his shares. The subsequent work by Shleifer and Vishny (1989) and Edlin and Stiglitz (1995), referred to earlier, showed how existing managers could take actions to reduce the effectiveness of competition for management, i.e., the threat of takeovers, by increasing asymmetries of information.

So far, we have discussed two of the three pillars of the modern theory of the firm: corporate finance and corporate governance. The third is *organizational design.* In a world with perfect information, organizational design too is of little moment. In practice, it is of central concern to businesses. For example, as we have already discussed, an organizational design that has alternative units performing comparable tasks can enable a firm to glean information on the basis of which better incentive systems can be based. (Nalebuff and Stiglitz, 1983a, b). But there is another important aspect of organization design. Even if individuals are well intentioned, with limited information, mistakes get made. To err is human. Raaj K. Sah and I, in a series of papers (1985, 1986, 1988a, b, 1991) explored the consequences of alternative organizational design and decision-making structures for organizational mistakes: for instance, whether good projects get rejected or bad projects get accepted. We suggested that, in a variety of circumstances, decentralized polyarchical organizational structures have distinct advantages (see also Sah, 1991; Stiglitz, 1989d). These papers are just beginning to spawn a body of research; see, for example, Bauke Visser (1998), Amar Bhidé (2001), and Michael Christensen and Thorbjorn Knudsen (2002).

B. Macroeconomics

With these points made, we can return to the important area of *macroeconomics.* The central macroeconomic issue is unemployment. The models I described earlier explained why unemployment could exist *in equilibrium.* But much of macroeconomics is concerned with *dynamics,* with explaining why sometimes the economy seems to amplify rather than absorb shocks, and why the effects of shocks may long persist. In joint work with Bruce Greenwald and Andy Weiss, I have shown how theories of asymmetric information can help provide explanations of these phenomena. (For an early survey, see Greenwald and Stiglitz [1987a, 1988b, 1993b] and Stiglitz [1988b, 1992a].) The imperfections of capital markets—the phenomena of credit and equity rationing which arise because of information asymmetries—are key. They lead to risk-averse behavior of firms and to households and firms being affected by cash flow constraints.

Standard interpretations of Keynesian economics emphasized the importance of wage and price rigidities, but without a convincing explanation of how those rigidities arise. For instance, some theories had shown the importance of costs of adjustment of prices (Akerlof and Yellen, 1985; N. Gregory Mankiw, 1985). Still at issue, though, is why firms tend to adjust quantities rather than prices, even though the costs of adjusting quantities seem

greater than those of prices. The Greenwald-Stiglitz theory of adjustment (1989) provided an explanation based on capital market imperfections arising from information imperfections. In brief, it argued that the risks created by informational imperfections are generally greater for price and wage adjustments than from quantity adjustments. Risk-averse firms would make smaller adjustments to those variables for which the consequences of adjustment were more uncertain.

But even though wages and prices were not perfectly flexible, neither were they perfectly rigid, and indeed in the Great Depression, they fell by a considerable amount. There had been large fluctuations in earlier periods, and in other countries, in which there had been a high degree of wage and price flexibility. Greenwald and I (1987a, b, 1988b, c, d, 1989, 1990b, 1993a, b, 1995) argued that other market failures, in particular, the imperfections of capital markets and incompleteness in contracting, were needed to explain key observed macroeconomic phenomena. In debt contracts, which are typically not indexed for changes in prices, whenever prices fell below the level expected (or in variable interest rate contracts, whenever real interest rates rose above the level expected) there were transfers from debtors to creditors. In these circumstances, excessive downward price flexibility (not just price rigidities) could give rise to problems; Irving Fisher (1933) and Stiglitz (1999d) emphasize the consequences of differences in the speed of adjustment of different prices. These (and other) redistributive changes had large real effects, and could not be insured against because of imperfections in capital markets. Large shocks could lead to bankruptcy, and with bankruptcy (especially when it results in firm liquidation) there was a loss of organizational and informational capital.[24] Even if such large changes could be forestalled, until

there was a resolution, the firm's access to credit would be impaired, and for good reason. Moreover, without "clear owners" those in control would in general not have incentives to maximize the firm's value.

Even when the shocks were not large enough to lead to bankruptcy, they had impacts on firms' ability and willingness to take risks. Since all production is risky, shocks affect aggregate supply, as well as the demand for investment. Because firm net worth would only be restored over time, the effects of a shock persisted. By the same token, there were hysteresis effects associated with policy: An increase in interest rates which depleted firm net worth had impacts even after the interest rates were reduced. Firms that were bankrupted with high interest rates remain so. If firms were credit rationed, then reductions in liquidity could have particularly marked effects (Stiglitz and Weiss, 1992). Every aspect of macroeconomic behavior is affected: The theories helped explain, for instance, the seemingly anomalous cyclical behavior of inventories (the procyclical movements in inventories, counter to the idea of production smoothing, result from cash constraints and the resulting high shadow price of money in recessions); or of pricing (in recessions, when the "shadow price" of capital is high, firms do not find it profitable to invest in acquiring new customers by cutting prices). In short, our analysis emphasized the supply-side effects of shocks, the interrelationships between supply and demand side effects, and the importance of *finance* in propagating fluctuations.

Earlier, I described how the information paradigm explained credit rationing. A second important strand in our macroeconomic research explored the link between credit rationing and macroeconomic activity (Alan S. Blinder and Stiglitz, 1983), explained the role of banks as risk-averse firms, as information institutions involved in screening and monitoring, in determining the supply of credit (Greenwald and Stiglitz, 1990b, 1991, 2002; Stiglitz and Weiss, 1990), described the macroeconomic impacts of changes in financial regulations, and analyzed the implications for monetary policy under a variety of regimes, including dollarization (Stiglitz, 2001d). These differed in many respects from the traditional theories, such as those based on the transactions demand for

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[24] In traditional economic theories bankruptcy played little role, partly because control (who made decisions) did not matter, and so the change in control that was consequent to bankruptcy was of little moment, partly because with perfect information, there would be little reason for lenders to lend to someone, rather than extending funds through equity (especially if there were significant probabilities of, and costs to, bankruptcy). For an insightful discussion about control rights see Hart (1995).

money, the microfoundations of which were increasingly being discredited as money became increasingly interest bearing (the interest rate was not the opportunity cost of holding money) and as credit, not money, was increasingly being used for transactions. We also explained the importance of credit linkages (e.g., not only between banks and firms but among firms themselves) and their role in transmitting shocks throughout the economy. A large body of empirical work has subsequently verified the importance of credit constraints for macroeconomic activity, especially investment (see Kuh and Meyer (1957), Charles W. Calomiris and Hubbard (1990), and Hubbard (1990).

C. Growth and Development[25]

While most of the macroeconomic analysis focused on exploring the implications of imperfections of credit markets for cyclical fluctuations, another strand of our research program focused on growth. The importance of capital markets for growth had long been recognized; without capital markets firms have to rely on retained earnings. But how firms raise capital is important for their growth. In particular, "equity rationing"—especially important in developing countries, where informational problems are even greater—impedes firms' willingness to invest and undertake risks, and thus slows growth. Changes in economic policy which enable firms to bear more risk (e.g., by reducing the size of macroeconomic fluctuations, or which enhance firms' equity base, by suppressing interest rates, which result in firm's having larger profits) enhance economic growth. Conversely, policies, such as those associated with IMF interventions, in which interest rates are raised to very high levels, discourage the use of debt, forcing firms to rely more heavily on retained earnings.

The most challenging problems for growth lie in economic development. Typically, market failures are more prevalent in less developed countries, and these market failures are often associated with information problems—the very problems that inspired much of the research described in this paper (see Stiglitz, 1985b, 1986a, 1988a, 1989e, h, 1991a, 1997a; Braverman et al., 1993). While these perspectives help explain the failures of policies based on *assuming* perfect or well-functioning markets, they also direct attention to policies which might remedy or reduce the consequences of informational imperfections (World Bank, 1999).

One of the most important determinants of the pace of growth is the acquisition of knowledge. For developed countries, this requires investment in research; for less developed countries, efforts at closing the knowledge gap between themselves and more developed countries. Knowledge is, of course, a particular *form* of information, and many of the issues that are central to the economics of information are also key to understanding research—such as the problems of appropriability, the fixed costs associated with investments in research (which give rise to imperfections in competition), and the public good nature of information. It was thus natural that I turned to explore the implications in a series of papers that looked at both equilibrium in the research industry and the consequences for economic growth.[26] While it is not possible to summarize briefly the results, one conclusion does stand out: Market economies in which research and innovation play an important role are not well described by the standard competitive model, and that the market equilibrium, without government intervention, is not in general efficient.

D. Theory of Taxation[27]

One of the functions of government is to redistribute income. Even if it did not actively

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[25] For discussions of growth, see Greenwald et al. (1990) and Stiglitz (1990, 1992c, 1994a, b). The somewhat separate topic of development is analyzed in Stiglitz (1985b, 1986a, 1988a, 1989b, e, h, 1991a, 1993, 1995, 1996, 1997a, b, 1998b, 1999b, c, 2000c, 2001a, b), Sah and Stiglitz (1989a, b), Karla Hoff and Stiglitz (1990, 1998, 2001), Nicholas Stern and Stiglitz (1997), and Stiglitz and Shahid Yusuf (2000).

[26] There were, of course, several precursors to what has come to be called endogenous growth theory. See in particular, the collection of essays in Karl Shell (1967) and Anthony B. Atkinson and Stiglitz (1969). For later work, see, in particular, Dasgupta and Stiglitz (1980a, b, 1981, 1988), Dasgupta et al. (1982), and Stiglitz (1987c, d, 1990).

[27] The discussion of this section draws upon Mirrlees (1971, 1975a), Atkinson and Stiglitz (1976), Stiglitz (1982e, 1987f), Arnott and Stiglitz (1986), and Brito et al. (1990, 1991, 1995).

wish to redistribute, the government has to raise revenues to finance public goods, and there is a concern that the revenue be raised in an equitable manner, e.g., that those who are more able to contribute do so. But government has a problem of identifying these individuals, just as (for example) a monopolist may find it difficult to identify those who are willing to pay more for its product. Importantly, the self-selection mechanisms for information revelation that Rothschild and I had explored in our competitive insurance model or that I had explored in my paper on discriminating monopoly can be applied here. (The problem of the government, maximizing social "profit," i.e., welfare, subject to the information constraints, is closely analogous to that of the monopolist, maximizing private profit subject to information constraints. For this reason, Mirrlees' (1971) paper on optimal taxation, though not couched in information-theoretic terms, was an important precursor to the work described here.)

The critical question for the design of a tax system thus becomes *what is observable.* In older theories, in which information was perfect, lump-sum taxes and redistributions made sense. If ability is not directly observable, the government had to rely on other observables—like income—to make inferences; but, as in all such models, market participants, as they recognize that inferences are being made, alter their behavior. In Mirrlees (1971) only income was assumed observable. But in different circumstances, either more or less information might be available. It might be possible to observe hours worked, in which case wages would be observable. It might be possible to observe the quantity of each good purchased by any particular individual or it might be possible to observe only the aggregate quantity of goods produced.

For each information structure, there is a *Pareto-efficient tax structure,* that is, a tax structure such that no group can be made better off without making some other group worse off. The choice among such tax structures depends on the social welfare function, including attitudes towards inequality.[28] While this is not the

occasion to provide a complete description of the results, two are worth noting: What had been thought of as optimal commodity tax structures (Frank P. Ramsey, 1927) were shown to be part of a Pareto-efficient tax system only under highly restricted conditions, e.g., that there was no income tax (see Atkinson and Stiglitz, 1976; Sah and Stiglitz, 1992; Stiglitz, 1998a). On the other hand, it was shown that in a central benchmark case, it was not optimal to tax interest income.

E. *Theory of Regulation and Privatization*

The government faces the problems posed by information asymmetries in regulation as well as in taxation. Over the past quarter century, a huge literature has developed making use of self-selection mechanisms (see, for example, David E. M. Sappington and Stiglitz [1987a]; Jean-Jacques Laffont and Tirole [1993]), allowing far better and more effective systems of regulation than had existed in the past. An example of a sector in which government regulation is of particular importance is banking; we noted earlier that information problems are at the heart of credit markets, and it is thus not surprising that market failures be more pervasive, and the role of the government more important in those markets (Stiglitz, 1994d). Regulatory design needs to take into account explicitly the limitations in information (see, e.g., Hellman et al., 2000; Patrick Honahan and Stiglitz, 2001; Stiglitz, 2001c; Greenwald and Stiglitz, 2002).

The 1980's saw a strong movement towards privatizing state enterprises, even in areas in which there was a natural monopoly, in which case government ownership would be replaced with government regulation. While it was apparent that there were frequently problems with government ownership, the theories of imperfect information also made it clear that even the

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[28] In that sense, Mirrlees' work confounded the two stages of the analysis. He described the point along the

Pareto frontier that would be chosen by a government with a utilitarian social welfare function. Some of the critical properties, e.g., the zero marginal tax rate at the top, were, however, characteristics of *any* Pareto-efficient tax structure, though that particular property was not *robust*—that is, it depended strongly on his assumption that relative wages between individuals of different abilities were fixed (see Stiglitz, 2002a).

best designed regulatory systems would work imperfectly. This naturally raised the question of under what circumstances we could be sure that privatization would enhance economic welfare. As Herbert A. Simon (1991), winner of the 1978 Nobel Prize, had emphasized, both public and private sectors face information and incentive problems; there was no compelling theoretical argument for why large private organizations would solve these incentive problems better than public organizations. In work with Sappington (1987b), I showed that the conditions under which privatization would necessarily be welfare enhancing were extremely restrictive, closely akin to those under which competitive markets would yield Pareto-efficient outcomes (see Stiglitz [1991b, 1994c] for an elaboration and applications).

VI. Some Policy Debates

The perspectives provided by the new information paradigm not only shaped theoretical approaches to policy, but in innumerable concrete issues also led to markedly different policy stances from those wedded to the old paradigm.

Perhaps most noted were the controversies concerning development strategies, where the *Washington consensus* policies, based on market fundamentalism—the simplistic view of competitive markets with perfect information, inappropriate even for developed countries, but particularly inappropriate for developing countries—had prevailed since the early 1980's within the international economic institutions. Elsewhere, I have documented the failures of these policies in development (Stiglitz, 1999c), as well as in managing the transition from communism to a market economy (see, for instance, Athar Hussein et al., 2000; Stiglitz [2000a, 2001e]) and in crisis management and prevention (Stiglitz, 2000b). Ideas matter, and it is not surprising that policies based on models that depart as far from reality as those underlying the Washington consensus so often led to failure.

This point was brought home perhaps most forcefully by the management of the East Asia crisis which began in Thailand on July 2, 1997. While I have written extensively on the many dimensions of the failed responses (Jason Furman and Stiglitz, 1998; Stiglitz, 1999e), here I want to note the close link between these failures and the theories put forward here. Our work had emphasized the importance of maintaining the credit supply and the risks of (especially poorly managed) bankruptcy. Poorly designed policies could lead to an unnecessarily large reduction in credit availability and unnecessary large increases in bankruptcy, both leading to large adverse effects on aggregate supply, exacerbating the economic downturn. But this is precisely what the IMF did: by raising interest rates to extremely high levels in countries where firms were already highly leveraged, it forced massive bankruptcy, and the economies were thus plunged into deep recession. Capital was not attracted to the country, but rather fled. Thus, the policies even failed in their stated purpose, which was to stabilize the exchange rate. There were strong hysteresis effects associated with these policies: when the interest rates were subsequently lowered, firms that had been forced into bankruptcy did not become "unbankrupt," and the firms that had seen their net worth depleted did not see an immediate restoration. There were alternative policies available, debt standstills followed by corporate financial restructurings, for example; while these might not have avoided a downturn, they would have made it shorter and more shallow. Malaysia, whose economic policies conformed much more closely to those that our theories would have suggested, not only recovered more quickly, but was left with less of a legacy of debt to impair its future growth, than did neighboring Thailand, which conformed more closely to the IMF's recommendation. (For discussions of bankruptcy reform motivated by these experiences see Marcus Miller and Stiglitz, 1999; Stiglitz, 2000e.)

On another front, the *transition from communism to a market economy* represents one of the most important economic experiments of all time, and the failure (so far) in Russia, and the successes in China, shed considerable light on many of the issues which I have been discussing. The full dimension of Russia's failure is hard to fathom. Communism, with its central planning (requiring more information gathering, processing, and dissemination capacity than could be managed with *any* technology), its lack of incentives, and its system rife with distortions, was viewed as highly inefficient. The movement to a market, it was assumed, would

bring enormous increases in incomes. Instead, incomes plummeted, a decline confirmed not only by GDP statistics and household surveys, but also by social indicators. The numbers in poverty soared, from 2 percent to upwards of 40 percent, depending on the measure used. While there were many dimensions to these failures, one stands out: the privatization strategy, which paid little attention to the issues of corporate governance which we stressed earlier. Empirical work (Stiglitz, 2001e) confirms that countries that privatized rapidly but lacked "good" corporate governance did not grow more rapidly. Rather than providing a basis for wealth creation, privatization led to asset stripping and wealth destruction (Hussein et al., 2000; Stiglitz, 2000a).

VII. Beyond Information Economics

We have seen how the competitive paradigm that dominated economic thinking for two centuries was not robust, did not explain key economic phenomena, and led to misguided policy prescriptions. The research over the past 30 years on information economics that I have just described has focused, however, on only one aspect of my dissatisfaction with that paradigm. It is not easy to change views of the world, and it seemed to me the most effective way of attacking the paradigm was to keep within the standard framework as much as possible. I only varied one assumption—the assumption concerning perfect information—and in ways which seemed to me highly plausible.

There were other deficiencies in the theory, some of which were closely connected. The standard theory assumed that technology and preferences were fixed. But changes in technology, R & D, are at the heart of capitalism. The new information economics—extended to incorporate changes in knowledge—at last began to address systematically these foundations of a market economy.

As I thought about the problems of development, I similarly became increasingly convinced of the inappropriateness of the assumption of fixed preferences, and of the importance of embedding economic analysis in a broader social and political context. I have criticized the Washington consensus development strategies partly on the grounds that they per-

ceived of development as nothing more than increasing the stock of capital and reducing economic distortions. But development represents a far more fundamental transformation of society, including a change in "preferences" and attitudes, an acceptance of change, and an abandonment of many traditional ways of thinking (Stiglitz, 1995, 1999c). This perspective has strong policy implications. For instance, some policies are more conducive to effecting a development transformation. Many of the policies of the IMF—including the manner in which in interacted with governments, basing loans on conditionality—were counterproductive. A fundamental change in development strategy occurred at the World Bank in the years I was there, one which embraced this more comprehensive approach to development. By contrast, policies which have ignored social consequences have frequently been disastrous. The IMF policies in Indonesia, including the elimination of food and fuel subsidies for the very poor as the country was plunging into depression, predictably led to riots. The economic consequences are still being felt.

In some ways, as I developed these perspectives, I was returning to a theme I had raised 30 years ago, during my work on the efficiency wage theory in Kenya. In that work I had suggested psychological factors—morale, reflecting a sense that one is receiving a fair wage—could affect efforts, an alternative, and in some cases more persuasive reason for the efficiency wage theory. It is curious how economists have almost studiously ignored factors, which are not only the center of day-to-day life, but even of business school education. Surely, if markets were efficient, such attention would not be given to such matters, to issues of corporate culture and intrinsic rewards, unless they were of some considerable importance. And if such issues are of importance within a firm, they are equally important within a society.

Finally, I have become convinced that the dynamics of change may not be well described by equilibrium models that have long been at the center of economic analysis. Information economics has alerted us to the fact that history matters; there are important hysteresis effects. Random events—the Black Plague, to take an extreme example—have consequences that are irreversible. Dynamics may be better described

by evolutionary processes and models, than by equilibrium processes. And while it may be difficult to describe fully these evolutionary processes, this much is already clear: there is no reason to believe that they are, in any general sense, "optimal." (I discussed these issues briefly in Stiglitz [1975b, 1992e, 1994c] and Sah and Stiglitz [1991]; some of the problems are associated with capital market imperfections.)

Many of the same themes that emerged from our simpler work in information economics applied here. For instance, in the information-theoretic models discussed above we showed that multiple equilibria (some of which Pareto-dominated others) could easily arise. So, too, here (Stiglitz, 1995). This in turn has several important consequences, beyond the observation already made that history matters. First, it means that one cannot simply predict where the economy will be by knowing preferences, technology, and initial endowments. There can a high level of indeterminacy (see, e.g., Stiglitz, 1973c) Second, as in Darwinian ecological models, the major determinant of one's environment is the behavior of others, and their behavior may in turn depend on their beliefs about others' behavior (Hoff and Stiglitz, 2001). Third, government intervention can sometimes move the economy from one equilibrium to another; and having done that, continued intervention might not be required.

VIII. The Political Economy of Information

Information affects political processes as well as economic ones. First, we have already noted the distributive consequences of information disclosures. Not surprisingly, then, the "information rules of the game," both for the economy and for political processes, can become a subject of intense political debate. The United States and the IMF argued strongly that lack of transparency was at the root of the 1997 financial crisis, and said that the East Asian countries had to become more transparent. The attention to quantitative data on capital flows and loans by the IMF and the U.S. Treasury could be taken as conceding the inappropriateness of the competitive paradigm (in which *prices* convey all the relevant information); but the more appropriate way of viewing the debate

was *political,* a point which became clear when it was noted that partial disclosures could be of only limited value. Indeed, they could possibly be counterproductive, as capital would be induced to move through channels involving less disclosure, channels like off-shore banking centers, which were also less well regulated. When demands for transparency went beyond East Asia to Western hedge funds and offshore banking centers, suddenly the advocates of more transparency became less enthralled, and began praising the advantages of partial secrecy in enhancing incentives to gather information. The United States and the Treasury then opposed the OECD initiative to combat money laundering through greater transparency of offshore banking centers—these institutions served particular *political and economic interests*—until it became clear that terrorists might be using them to help finance their operations. At that point, the balance of American interests changed, and the Treasury changed its position.

Political processes inevitably entail asymmetries of information (for a more extensive discussion, see Patrick D. Moynihan, 1998; Stiglitz, 2002b): our political leaders are *supposed* to know more about threats to defense, about our economic situation, etc., than ordinary citizens. There has been a delegation of responsibility for day-to-day decision-making, just as there is within a firm. The problem is to provide incentives for those so entrusted to act on behalf of those who they are supposed to be serving—the standard principal-agent problem. Democracy—contestability in political processes—provides a check on abuses of the powers that come from delegation just as it does in economic processes; but just as we recognize that the takeover mechanism provides an imperfect check on management, so too we should recognize that the electoral process provides an imperfect check on politicians. As in the theory of the firm where the current management has an incentive to *increase* asymmetries of information in order to enhance market power, so too in public life. And as disclosure requirements—greater transparency—can affect the effectiveness of the takeover mechanism and the overall quality of corporate governance, so too these factors can affect political contestability and the quality of public governance.

In the context of political processes, where "exit" options are limited, one needs to be particularly concerned about abuses. If a firm is mismanaged—if the managers attempt to enrich themselves at the expense of shareholders and customers and entrench themselves against competition, the damage is limited—customers, at least, can switch. But in political processes, switching is not so easy. If all individuals were as selfish as economists have traditionally modeled them, matters would indeed be bleak, for—as I have put it elsewhere—ensuring the public good is itself a public good. But there is a wealth of evidence that the economists' traditional model of the individual is too narrow—and that indeed intrinsic rewards, e.g., of public service, can be even more effective than extrinsic rewards, e.g., monetary compensation (which is not to say that compensation is not of some importance). This public spiritedness (even if blended with a modicum of self-interest) is manifested in a variety of civil society organizations, through which individuals voluntarily work together to advance their perception of the collective interests.

There are strong incentives on the part of those in government to reduce transparency. More transparency reduces their scope for action—it not only exposes mistakes, but also corruption (as the expression goes, "sunshine is the strongest antiseptic"). Government officials may try to enhance their power by trying to advance specious arguments for secrecy, and then saying, in effect, to justify their otherwise inexplicable or self-serving behavior, "trust me ... if you only knew what I knew."

There is a further rationale for secrecy, from the point of view of politicians: Secrecy is an artificially created scarcity of information, and like most artificially created scarcities, it gives rise to rents, rents which in some countries are appropriated through outright corruption (selling information). In other contexts these rents become part of a "gift exchange," as when reporters trade "puff pieces" and distorted coverage in exchange for privileged access to information. I was in the unfortunate position of watching this process work, and work quite effectively. Without unbiased information, the effectiveness of the check that can be provided by the citizenry is limited; without good information, the contestability of the political processes can be undermined.

One of the lessons of the economics of information is that these problems cannot be fully resolved, but that laws and institutions can decidedly improve matters. Right-to-know laws, for example, which require increased transparency, have been part of governance in Sweden for 200 years; they have become an important if imperfect check on government abuses in the United States over the past quarter century. In the past five years, there has become a growing international acceptance of such laws; Thailand has gone so far as to include such laws in its new constitution. Regrettably, these principles of transparency have yet to be endorsed by the international economic institutions.

IX. Concluding Remarks

In this article I have traced the replacement of one paradigm with another. The deficiencies of the neoclassical paradigm—the failed predictions, the phenomena that were left unexplained—made it inevitable that it would be challenged. One might ask, though, how can we explain the persistence of this paradigm for so long? Despite its deficiencies, the competitive paradigm did provide insights into many economic phenomena. There are some markets in which the issues which we have discussed are not important—the market for wheat or corn—though even there, pervasive government interventions make the reigning competitive paradigm of limited relevance. The underlying forces of demand and supply are still important, though in the new paradigm, they become only part of the analysis; they are not the whole analysis. But one cannot ignore the possibility that the survival of the paradigm was partly because the belief in that paradigm, and the policy prescriptions that were derived from it, has served certain interests.

As a social scientist, I have tried to follow the analysis, wherever it might lead. My colleagues and I know that our ideas can be used or abused—or ignored. Understanding the complex forces that shape our economy is of value in its own right; there is an innate curiosity about how this system works. But, as Shakespeare said, "All the world's a stage, and all the men and women merely players." Each of us in our own way, if only as a voter, is an actor in this grand drama. And what we do is affected by

our perceptions of how this complex system works.

I entered economics with the hope that it might enable me to do something about unemployment, poverty, and discrimination. As an economic researcher, I have been lucky enough to hit upon some ideas that I think do enhance our understanding of these phenomena. As an educator, I have had the opportunity to reduce some of the asymmetries of information, especially concerning what the new information paradigm and other developments in modern economic science have to say about these phenomena, and to have had some first-rate students who, themselves, have pushed the research agenda forward.

As an individual, I have however not been content just to let others translate these ideas into practice. I have had the good fortune to be able to do so myself, as a public servant both in the American government and at the World Bank. We have the good fortune to live in democracies, in which individuals can fight for their perception of what a better world might be like. We as academics have the good fortune to be further protected by our academic freedom. With freedom comes responsibility: the responsibility to use that freedom to do what we can to ensure that the world of the future be one in which there is not only greater economic prosperity, but also more social justice.

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